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THE JOURNAL
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THE SEISMICITY OF THE ARCTIC*

By Ernest A. Hodgson

The Arctic—that polar area lying within the Arctic Circle—presents a composite scientific problem of peculiar interest. Seismology permits us to study one phase of that problem without recourse to the usual elaborate equipment of the explorer. The research presents, moreover, an extraordinary continuity and generality.

The earlier seismological investigations which shed light on the question of the seismicity of the Arctic are those of John Milne. Beginning in 1899, this enthusiastic student, teacher, and organizer assembled year by year the records of his widely distributed seismographs. The results to and including those of 1906 were embodied in a report presented before the British Association for the Advancement of Science, at the Leicester Meeting in August 1907. Of the 474 "world-shaking earthquakes" so studied, only three were found to have had epicentres within the Arctic Circle.[1] These were all near to the island Jan Mayen, which lies north and somewhat east of Iceland. We shall first direct our attention to this part of the Arctic, so uniquely designated as seismic by the researches of Milne.

The islands of Iceland and Jan Mayen are volcanic, the latter lying at the extreme north end of a mid-Atlantic sub-oceanic plateau, which extends south as far as the Azores; the depth of the covering ocean being generally about 2,000 metres, and never greater than 4,000 meters.[2] Iceland is an island, rising out of this

*Prepared for the American Geophysical Union, Section of Seismology, Washington, D.C., April 26, 1929.

same plateau, about 300 miles long from east to west, by 200 miles wide from north to south. It is approximately 20° W. Long. Its extreme northern point just touches the Arctic Circle. It lies, thus, outside the region we are considering but should receive some attention in this paper as it is so close to the most actively

Figure 1

seismic area of the Arctic and also because it possesses a rich historic literature containing frequent references to earthquakes, from which we may learn something of the nature of the region immediately to the north of it.

In the Report of the British Association for the Sheffield

Meeting of 1910, there appears[3] a "List of the Destructive Earthquakes of Iceland for the years 1013 to 1899". The seismic areas of the island appear to lie in the north-east and south-west sectors respectively. The north-east sector is practically uninhabited. The west half of the southern coast is the only part of the island suitable for grazing or any form of agriculture. Practically all the inhabitants of Iceland are to be found in this section which is a low-lying plain sloping very gradually to the north where it is terminated by the high rocky table-land which forms the major part of the island. Hekla, the famous volcano of Iceland, lies at the north-eastern corner of this narrow coastal plain. The projection of the south-western peninsula beneath the ocean is the scene of frequent sub-oceanic volcanic disturbances, but, as noted by Montessus de Ballore[2], these do not appear to be associated with the seismic tremors of the island. It is to be noted that volcanic eruptions in these regions (as in other parts of the world) cause the earth to tremble over a limited area; but that the world-shaking quakes studied by Milne, and those of more recent date to which reference will presently be made are not, in general, associated with volcanic eruptions.

The International Seismological Association, at the Hague Meeting in 1907, decided to establish a seismic station at Reykjavik—the chief town of Iceland, situated on the west coast of the south-west coastal plain. This was done in 1908. The instrument installed was a Mainka 135 kg., mechanically-recording, horizontal seismograph, having a static magnification of 40 to 75, a free period of 6 seconds, and a damping ratio of 13:1. This was placed to record the north-south component. In spite of the relatively weak sensitivity of such an instrument, the records for this station for 1910 (apparently the first to be published) show a total of 123 quakes. On January 22, 1910, a strong earthquake occurred at $\phi = 67°\ 56'$ N.: $\lambda = 16°\ 45'$ W., a point about 400 km. from the station. A total of 67 aftershocks were registered at Reykjavik[4] within the following 24 hours. The other 55 tremors were distributed throughout the other 364 days of 1910.

A seismic station was in operation at Adventbay in Spitzbergen at $\phi = 78°\ 13'$ N.: $\lambda = 15°\ 36'$ E—the most northerly position at which a seismograph has ever been placed—for about 7 months

during the winter and spring of 1911-12. This was under the auspices of the Hauptstation für Erdbebenforschung in Strassburg. A report of the work is given in *Beiträge zur Geophysik* for 1914. The observations[5] cover too short a time to permit of very definite conclusions. Besides the more distant earthquakes registered there were six "nahbeben" from distances ranging from 160 to 300 km. Of these the largest was that of December 4, 1911. It was computed that this epicentre lay at $\phi = 79°$ N.: $\lambda = 26°.2$ E.—about 250 km. east of Spitzbergen. This quake was registered on the Bosch, photographic, horizontal seismograph at Ottawa as a series of *L*-waves preceded some 4 minutes by a faint emergence. The record could not be read for distance. At Adventbay it was experienced as a shock of "from 7 to 8 on the Rossi-Forel Scale." We may conclude from these researches that Spitzbergen is also a relatively active seismic region. Nevertheless, we shall later find evidence to show that very severe shocks are, apparently, not often experienced there.

We note, then, from an examination of the above sources of information available previous to 1911, that:

(1) of the entire Arctic region only that part lying between Iceland and Spitzbergen registered as seismic on the Milne seismographs for the period 1899-1906.

(2) Historic records of earthquakes in Iceland (1013-1899) and the instrumental records obtained at Reykjavik (1910) show that the island has distinct seismic areas which suffer repeated shocks of a more or less limited nature which are due to volcanic action.

(3) The larger earthquakes—the tectonic, world-shaking tremors—do not seem to be directly associated with volcanic action.

(4) A tectonic earthquake which occurred 250 km. east of Spitzbergen, of intensity 7 to 8 (Rossi-Forel) at Spitzbergen is just barely registered on a Bosch, photographic seismograph at Ottawa—a distance of approximately 5500 km.

We may now turn our attention to the more recent and complete sources of data secured at the increasingly-numerous seismographic stations by means of more sensitive instruments. Since 1911 the Dominion Observatory has made a practice of compiling

these data for the purpose of deducing the epicentres of the larger quakes, of which at least a trace was found at Ottawa. The locations for 1926 have just been finished. Those for the first ten months of 1927 are also available in manuscript form. This completes a period of nearly sixteen years, during which time a continuous investigation has been in progress which would not fail to indicate any large earthquake occurring in the region we are studying—the Arctic.

For the period 1913 to June 1925, inclusive, the International Seismological Summaries have published the results of a similar service under the direction of Prof. Turner of Oxford. In this case all earthquakes of which a record was obtained at any station were included in the investigations.

These two series of locations have been studied with a view to obtaining every indication of seismicity in the Arctic. All epicentres of either series with latitudes of 66° or more have been included in the tabular presentation of the data which is given in the appendix of this paper.

A study of the table reveals the following conditions, namely:

(1) Nearly all the smaller records are from epicentres near Iceland or Jan Mayen. Probably these are due to volcanic rather than tectonic quakes.

(2) Of the well-determined epicentres, presumably from tectonic quakes, all but three lie in the Jan Mayen—Iceland region, being concentrated near Jan Mayen.

(3) One of the two other seismic areas designated within the Arctic Circle by almost sixteen years of uninterrupted recording is at approximately $\phi = 77°$ N.: $\lambda = 127°$ E., off the mouth of the Lena River, Siberia, at which two quakes occurred within about nine hours of each other, at practically the same epicentre, on May 30, 1923. The independent locations by Ottawa and by Oxford agree within close limits.

(4) The remaining seismic area of the Arctic is represented by the quake of November 16, 1920, at approximately $\phi = 72°$ N.: $\lambda = 127°$ W., north and east of the mouth of the Mackenzie River, Canada. The independent locations of Ottawa and Oxford agree almost exactly. There can be no doubt whatever regarding the accuracy of this location.

A study of our Ottawa records for these well-defined Arctic locations shows that, in general, they are small: in many cases the values of 0 and Δ could not be determined from them, and were only made possible by the assembled data from other stations as used in the location work. These incomplete Arctic records resemble those of a series of rather ill-defined but interesting and important records which have been the subject of study at Ottawa for several years. In all, more than a hundred of them have been noted from July 1924 to date. These quakes present, in general, the following characteristics:

(1) The duration of the tremors is seldom more than five or ten minutes.
(2) The north-south component is usually more pronounced.
(3) A value for distance is almost never possible, but they come presumably from epicentres at a distance of 1,000 km.—less or more.
(4) No press reports of tremors within this distance agree with the times of the quake. (There is one possible exception—that of quake No. 3316, December 2, 1928, reported in the press as having been felt in northern Ontario; the exact date of the quake as reported in the press is uncertain.)

The serial numbers and dates of the 106 earthquakes of this type, registered at Ottawa since July 1924, are tabulated in the appendix of this paper. It will be noted that there does not seem to be any correlation of these with the seasons. It is assumed that there is a region of fairly continuous seismic activity lying to the north of Ottawa, and beyond the limits of population. It is to be remarked that the Arctic Circle is approximately 1600 km. north of Ottawa.

The study of Arctic seismic conditions has been reopened within the past few years. In *Science* for September 3, 1926, we read that the Danes intend to establish a seismic station on Jan Mayen. Nothing further seems to have been published which would indicate that this proposed installation is under way. Such a station would lie in the very heart of the most actively seismic region of the Arctic.

The Reykjavik station was reopened by the Danes in 1926. The records have since appeared regularly. From May 1, 1926,

to January 31, 1929, a total of 87 quakes were registered of which 48 may be characterized as "local". Since 1927 the station has been equipped with an E-W component as well as the N-S instrument of the earlier regime.

The Geodetic Institute of Denmark has established a first-class, fully-equipped station at Copenhagen, and has a subsidiary station at Scoresby-Sund, in eastern Greenland, at $\phi = 70° 29'$ N.: $\lambda = 21° 57'$ W. This station, so near the Jan Mayen seismic region, is equipped with three Galitzin pendulums with photo-galvanometric registration, one for each component. The first bulletin, covering the period from January 1, 1928, to August 31 of that year has just been received. It shows a total of 131 earthquakes recorded in the eight months covered.

Dominion Observatory,
Ottawa, Canada,
April 20, 1929.

ARCTIC LOCATIONS BY OXFORD AND BY OTTAWA, 1911 TO 1927

L	M	N	Date	Ottawa		Oxford		X		Y
				ϕ	λ	ϕ	λ			
1	1	122	Jan. 22 '10	67° 56′ N	16° 45′ W	.....	.....	(a)	..	1
2	2	423	July 26 '13	66°.1 N	18°.1 W	67°.5N	18°.6W	(b)	..	1
3	A	574	June 1 '15	80° N	4°.9 E	77°.0N	7°.0E	..	..	3
4	..	....	Dec. 6 '16	.....	.....	87°.0N	50°.0E	(c)	..	3
5	..	....	May 14 '17	.....		(72°.0N)	(2°.8W)	(d)	..	4
6	..	791	Aug. 21 '17	.....	.....	(72°.0N)	(2°.8W)	(d)	(e)	4
7	..	....	Oct. 20 '18	.....	.....	(72°.0N)	(2°.8W)	(d)	..	4
8	..	....	Oct. 26 '18	.....	.....	(72°.0N)	(2°.8W)	(d)	..	5
9	..	944	Nov. 30 '18	.....	.....	(70°.1N)	(132°.0E)	(e)	(f)	4
10	..	967	Feb. 2 '19	39°.5 N	30°.5 E	72°.0N	2°.8W	(d)	(g)	3
11	..	968	Feb. 15 '19	.....	.....	(68°.2N)	(13°.0W)	(e)	..	5
12	..	....	Sep. 12 '19	.....	.....	(72°.0N)	(2°.8W)	(d)	..	5
13	3	1132	Nov. 16 '20	72° N	126°.5 W	71°.8N	127°.0W	(h)	..	1
14	..	....	July 20 '21	.....	.....	(70°.0N)	(11°.0W)	..	..	5
15	B	1226	Aug. 23 '21	66° N	22° W	67°.5N	18°.6W	(i)	..	2
16	C	1274	Apr. 8 '22	72° N	8°.5 W	72°.0N	8°.5W	(j)	..	1
17	..	....	Sep. 24 '22	.....	.....	(75°.0N)	(100°.0E)	..	..	5
18	4	1477	May 30 '23	77° N	128° E	76°.5N	127°.0E	(k)	..	1
19	5	1479	May 30 '23	77° N	125° E	76°.5N	127°.0E	(k)	..	5
20	..	....	June 17 '23	.....	.....	(68°.5N)	(19°.5W)	..	..	1
21	6	1615	Oct. 10 '23	70° N	14° W	71°.0N	12°.0W	(l)	..	2
22	..	1649	Nov. 11 '23	.....	.....	(84°.0N)	(100°.0E)	(e)	..	5
23	D	1719	Mar. 12 '24	75° N	7°.8 E	(72°.8N)	(2°.5E)	(m)	..	4
24	..	1833	July 19 '24	.....	.....	(72°.8N)	(2°.5E)	(e)	..	5
25	..	....	July 25 '24	.....	.....	(72°.5N)	(16°.0E)	..	..	5
26	..	1852	Aug. 11 '24	.....	.....	(82°.0N)	(120°.0E)	(e)	..	5
27	..	1877	Sep. 7 '24	.....	.....	(82°.0N)	(10°.0E)	(e)	..	5
28	..	....	Sep. 24 '24	.....	.....	(82°.0N)	(10°.0E)	..	..	5
29	7	1904	Oct. 10 '24	70° N	18° W	(71°.7N)	(17°.0W)	..	..	4
30	8	1905	Oct. 10 '24	71° N	17°.5 W	(71°.7N)	(17°.0W)	..	..	4
31	..	1913	Oct. 19 '24	.....	.....	(79°.0N)	(110°.0E)	(e)	..	5
32	..	1938	Dec. 14 '24	.....	.....	(82°.0N)	(38°.0W)	(e)	(n)	5
33	..	....	Feb. 18 '25	.....	.....	(69°.0N)	(145°.0E)	..	..	5
34	E	2290	Nov. 28 '25	70° N	19° W	.....	.....	(o)	..	5
35	F	2505	July 14 '26	66° N	166° W	.....	.....	(0)	..	3
36	9	2977	Oct. 30 '27	73° N	10°.8 W	.....	.....	(0)	..	2

L—Tabular serial number; M—Map designation number; N—the Ottawa quake serial number; X—Index to notes; Y—the index of reliability on a scale of 5 where 1 indicates a location which is probably correct to the nearest degree of arc; and 5 indicates a location which is highly uncertain, even as to the general sector.

NOTES TO TABLE:

(a) Tams gives (4) $\phi = 67°.9$ N.; $\lambda = 17°.1$ W. Pulkova gives $\phi = 68°$ N.; $\lambda = 17°$ W. Harboe (9) accepts Tams location as confirmed by his (Harboe's) local investigations.

(b) Oxford location adopted from Pulkova determination. Mainka (6) gives the data obtained at Reykjavik.

(c) No trace at Ottawa. Oxford location based on records from 15 stations. Result given without reservation. This is the most northerly epicentre indicated.

(d) An epicentre frequently indicated by Oxford.

(e) An illegible trace only on Ottawa seismograms: no location made at Ottawa from the data submitted (irreconcilable or meagre).

(f) Adopted by Oxford from De Bilt determination.

(g) Ottawa location is evidently in error. Oxford location is approximate, but is in the proper region.

(h) A perfectly definite location, arrived at independently at Oxford and at Ottawa from good data: the two locations agree in the determination of 0 (time at origin) to within 3 seconds.

(i) Uccle gives $\phi = 65°.6$ N.: $\lambda = 22°.1$ W. De Bilt and Coimbra report the quake as having occurred "near Iceland."

(j) Hamburg gives "near Jan Mayen Land." Sieberg (7) places the epicentre at $\phi = 71°.5$ N.: $\lambda = 8°.5$ W.

(k) Locations very indefinite. The two quakes differ in time by only 9h 26m 12s.

(l) A very sharply-defined record obtained at Ottawa.

(m) Zürich gives $\phi = 82°$ N.: $\lambda = 0°$ E. Strasbourg gives "Arctic Ocean, vicinity Spitzbergen." Oxford reads this as two quakes, differing in 0 by only 26 minutes.

(n) Oxford reads this as two quakes differing in 0 by 19 minutes.

(o) Oxford locations for this date have not yet appeared.

EARTHQUAKES DESIGNATED AS "LOCALS" REGISTERED AT OTTAWA, JULY 15, 1924 TO APRIL 20, 1929

1924

1830 July 15
1900 Sep. 30
1926 Nov. 15

1925

2000 Mar. 1
2001 " 1
2002 " 1
2006 " 7
2019 " 17
2020 " 17
2021 " 18
2027 " 21
2031 " 23
2032 " 23
2033 " 24
2052 Apr. 26
2053 " 27
2056 " 29
2063 May 5
2073 " 13
2094 " 28
2097 " 31
2108 June 10
2116 " 18
2147 July 6
2157 " 10
2167 " 27
2169 " 30
2191 Aug. 17
2197 " 23
2199 " 26
2101 " 29
2204 " 31
2211 Sep. 2
2219 " 10
2228 " 24
2239 Oct. 1
2247 Oct. 9
2248 " 12
2260 " 19
2261 " 19
2269 Nov. 1
2274 " 9
2286 " 19
2293 Dec. 6
2295 " 9
2303 " 11
2306 " 17

1926

2324 Jan. 6
2357 Feb. 16
2360 " 18
2375 Mar. 10
2401 Apr. 3
2425 " 28
2428 " 30
2429 May 3
2441 " 21
2477 June 29
2487 July 4
2493 " 10
2496 " 11
2521 " 25
2531 Aug. 1
2563 " 24
2655 Nov. 15
2656 " 19
2661 " 27
2665 Dec. 3
2678 " 29

1927

2712 Feb. 11
2764 Mar. 28
2766 " 30
2769 Apr. 1
2780 " 15
2786 " 25
2796 May 5
2822 June 9
2825 " 11
2832 " 18
2850 July 7
2852 " 8
2924 Sep. 6
2937 " 17
2991 Nov. 12

1928

3041 Jan. 20
3048 Feb. 1
3049 " 2
3073 Mar. 6
3076 " 8
3089 " 18
3101 Apr. 2
3102 Apr. 3
3107 " 10
3129 May 1
3147 " 17
3178 June 8
3239 Sep. 5
3248 " 14
3251 " 19
3258 Oct. 2
3260 " 7
3273 " 13
3287 " 30
3316 Dec. 2
3330 " 15
3333 " 17

1929

3397 Mar. 23

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C. Mainka, "Ergebnisse der Erdbebenstation Adventbay auf Spitzbergen in der Zeit vom 27. Oktober 1911 bis 18. Juni 1912." *Ibid* (pages 103-113).

A. Sieberg, "Spitzbergens Erdbeben und Tektonik." *Ibid* (pages 114-120).

[6]C. Mainka, "Übersicht über die an der Internationalen Erdbebenstation in Reykjavik registrierten Erdbebenstörungen, 1913 Mai-Juli." *Beiträge zur Geophysik, 13* (Kleine Mitteilungen), 85-87, Leipzig, 1914.

[7]A. Sieberg, "Bemerkungen zum Erdbeben auf Jan Mayen am 8. April 1922, und über die Erdbeben des subarktisch-atlantischen Bruchfeldes überhaupt," *Mitteilung aus der Hauptstation für Erdbebenforschung in Jena*, 1922.

[8]Science, No. 1653, September 3, 1926, page 223.

[9]E. G. Harboe, "Das islandische Erdbeben am 22. Januar 1910." *Beiträge zur Geophysik, 12* (Kleine Mitteilungen), 27-40, Leipzig, 1913.

OCCULTATIONS OF STARS

By R. K. Young

The Royal Astronomical Society of Canada is attempting to interest its members in the observations of occultations of stars by the moon. In the April number of this Journal we reprinted an article by E. W. Brown on this subject which amateurs should read. It will emphasize the great value of such observations. The amateur may make these observations with a small telescope. Table I gives a list of stars which will be occulted during 1930 as seen from Toronto. Columns 1, 2, 3, 4 are self-explanatory. Column 5 gives the 75th meridian time when the star will pass under the moon as seen from Toronto. This time is only approximate but should be accurate to a minute or so and in general is a little early rather than late. In order to view the occultation the observer should be ready at his telescope a few minutes before this time. The purpose of the observation is to determine the exact instant of disappearance or reappearance of the star. Column 6 gives the hour angle of the star at the instant of occultation. It is useful in estimating the altitude of the moon above the horizon. Column 7 gives the position angle from the centre of the moon of the point of the star's disappearance. Imagine a line, joining the centre of the moon to the north pole of the sky and another joining the centre of the moon with the star just on the edge of the moon, the position angle is the angle between these lines counted from the north around through the east. If the observer does not look for the star till it is very close to the moon, he may need to make use of this angle in order to know where to look for the star. Columns 10, 11, 12 give the same data for emersion as given in columns 5, 6, 7 for immersions.

The columns headed a and b under immersion and emersion enable an observer who lives some distance from Toronto to predict the time at which the star will be occulted or will emerge at his place of observation. Suppose the observer is situated $\Delta\lambda$ degrees of longitude west from Toronto and $\Delta\phi$ degrees of latitude north,

then for his point of observation the time of immersion will be the time given in column 5 plus

$$\Delta S \times a + \Delta\phi \times b \text{ minutes.}$$

We illustrate the use of the numbers by means of an example. Suppose the observer is situated in London, Ontario, and he is about to observe the occultation of λ Cancri on May 30.

The longitude and latitude of London are 80°15′ and 42°57′, respectively, while the same quantities for Toronto are 79°17′ and 43°40′. Hence

$$\Delta\lambda = 81°15' - 79°17' = +2°.0,$$
$$\Delta\phi = 42°57' - 43°40' = -0°.7.$$

The observer may obtain his latitude with sufficient accuracy from a geographic map by measurement. In the eighth and ninth columns we find for λ Cancri, $a = +0.2$ and $b = -2.7$; and in column 5, that the star will be occultated at Toronto at 75th meridian civil time at 19 h. 39 m. The observer at London will see the occultation at 75th meridian time.

$$19\text{h } 39\text{m} + (2.0 \times 0.2) + (-0.7 \times -2.7)\text{m} = 19\text{h } 41\text{m}.$$

Table II gives the values of $\Delta\lambda$ and $\Delta\phi$ for several points throughout the province.

TABLE II

Station	$\Delta\lambda$	$\Delta\phi$	Station	$\Delta\lambda$	$\Delta\phi$
o.	°	°		°	°
Toronto	0.0	0.0	Owen Sound.....	+1.7	+0.9
Hamiltn	+0.6	−0.4	Windsor.....	+3.8	−1.4
London.....	+2.0	−0.7	North Bay.....	+0.2	+2.8
Kingston.....	−2.8	+0.5	Lindsay.....	−0.5	+0.7
Ottawa.....	−3.7	+1.7	Little Current....	+2.7	+2.3

(*Table I is on the next two pages*)

TABLE I

Date 1930	Star	Dec.	Mag.	Immersion: 75th Meridian Civil Time	Hour Angle	Position Angle	a	b
				h m			m	m
*May 03	c Geminorum	+26°	5.5	23 15	+06 03	108°d	+0.2	−1.5
20	161 B Capricorni	−18	6.4	03 34	−02 52	23	−1.2	+2.4
29	134 B Geminorum	+27	6.5	19 40	+04 40	99 d	−0.4	−1.4
30	31 λ Cancri	+24	5.9	19 39	+03 40	156 d	+0.2	−2.7
June 03	308 B Leonis	+ 8	5.8	21 39	+02 59	149 d	−0.5	−2.2
10	σ Scorpii	−25	3.0	00 46	+01 23	162 d	.....	.....
11	38 B Sagittarii	−28	4.7	21 25	−03 38	74	−1.2	+1.7
12	62 B Sagittarii	−29	6.0	03 06	+01 56	80	−1.6	−0.7
* 14	86 B Capricorni	−24	6.2	23 50	−03 45	101	−0.9	+1.2
16	143 B Capricorni	−20	6.1	01 09	−03 12	50	−1.3	+1.9
29	107 B Leonis	+16	6.3	21 47	+05 58	78 d	−0.1	−1.1
*July 03	h Virginis	−10	5.4	23 45	+04 44	122 d	−0.5	−1.9
12	33 Capricorni	−21	5.3	22 06	−04 10	128	−0.2	+0.3
17	10 Ceti	−00	6.4	01 45	−03 17	37	−0.7	+2.2
17	77 Piscium	+05	6.4	22 57	−06 41	57	+0.2	+1.7
21	14H′ Tauri	+21	6.5	01 58	−06 00	115	+0.3	+0.9
Aug. 6	234 B Sagittarii	−28	5.9	19 33	−03 05	85 d	−1.3	+1.3
12	4 Ceti	−03	6.3	20 54	−06 04	68	0.0	+1.8
12	5 Ceti	−03	6.3	21 12	−05 46	60	0.0	+1.8
13	155 B Piscium	+03	6.5	21 34	−06 03	36	+0.1	+2.0
17	65 Arietis	+21	6.0	04 32	−01 25	26	.....	.....
Sept. 02	183 B Sagittarii	−29	6.2	18 08	−02 26	130 d	−1.1	+0.3
04	86 B Capricorni	−24	6.2	18 55	−03 17	116 d	−1.1	+0.9
05	143 B Capricorni	−20	6.1	20 14	−02 45	98 d	−1.5	+1.2
07	Ψ′ Aquarii	−09	4.5	22 30	−01 54	59 d	−1.5	+1.6
08	27 Piscium	−04	5.1	22 13	−02 50	63	−1.2	+1.8
09	29 Piscium	−03	5.1	00 50	−00 15	85	−2.4	−0.4
12	ρ Arietis	+18	5.6	20 34	−07 10	46	+0.5	+1.8
13	δ Arietis	+19	4.5	05 23	+01 32	113	.....	.....
13	133 B Tauri	+22	5.9	21 04	−06 41	91	+0.2	+1.2
14	33 Tauri	+23	6.0	00 33	−04 07	36	0.0	+2.3
14	161 B Tauri	+23	6.5	02 42	−00 59	139	.....	.....
* 15	136 Tauri	+28	4.6	23 55	−06 34	44	+0.7	+1.9
16	415 B Tauri	+28	6.1	03 06	−03 29	134	−1.9	+2.7
28	210 B Scorpii	−29	5.8	21 10	+03 27	24 d	.....	.....
Oct. 2	35 Capricorni	−22	6.0	18 56	−01 59	114 d	−2.1	−0.4
* 09	π Arietis	+17	5.2	23 06	−02 43	97	−1.7	+1.0
10	45 Arietis	+18	6.0	03 52	+00 15	126	.....	.....
24	α Scorpii	−26	1.3	15 52	+01 20	82 d	−1.9	−0.5
Nov. 02	4 Ceti	−03	6.3	17 06	−04 29	89 d	−0.7	+1.6
02	5 Ceti	−03	6.3	17 25	−04 11	83 d	−0.8	+1.7
03	155 Piscium	+03	6.5	17 14	−05 01	70 d	−0.3	+1.8
06	63 Arietis	+20	5.2	21 41	−02 52	38	−0.4	+2.3
10	49 Aurigae	+28	5.1	04 53	+01 21	73	−1.9	+0.1
* 11	28 Cancri	+24	6.1	23 26	−05 53	64	+0.2	+2.0
12	v^1 Cancri	+24	5.7	00 42	−04 39	57	−0.1	+2.7
12	v^2 Cancri	+24	6.4	01 34	−01 19	34	.....	.....
26	K Capricorni	−19	4.8	20 57	+03 22	00	.....	.....
Dec. 03	ρ Arietis	+18	5.6	17 58	−04 23	94 d	−0.8	+1.4
03	45 Arietis	+18	6.0	18 05	−04 15	14 d	+0.3	+2.6
06	136 Tauri	+28	4.6	18 53	−06 13	39	+0.6	+2.0
31	36 Arietis	+17	6.5	00 42	+04 20	52 d	−0.9	−0.2
31	63 Arietis	+21	5.2	16 05	−04 52	35 d	+0.2	+2.1
31	65 Arietis	+21	6.0	16 45	−04 13	64 d	−0.4	+1.8

*Emersion on the following day.
*d*Means that the star approaches the dark limb.

TABLE I

Date 1930		Star	Dec.	Mag.	Emersion: 75th Meridian Civil Time h	m	Hour Angle h	m	Position Angle		a m	b m
*May	03	c Geminorum	+26°	5.5	00	06	+06	54	283°		+0.4	−1.4
	20	161 B Capricorni	−18	6.4	04	37	−01	49	285	d	−2.2	+0.7
	29	134 B Geminorum	+27	6.5	20	36	+05	37	290		+0.1	−1.6
	30	31 λ Cancri	+24	5.9	20	22	+04	24	248		−1.0	−0.8
June	03	308 B Leonis	+ 8	5.8	22	38	+03	58	280		−0.8	−1.6
	10	σ Scorpii	−25	3.0	01	31	+02	08	229		.....	.....
	11	38 B Sagittarii	−28	4.7	22	30	−02	31	309	d	−0.9	+0.2
	12	62 B Sagittarii	−29	6.0	04	25	+03	14	268	d	−1.1	−1.2
*	14	86 B Capricorni	−24	6.2	01	03	−02	32	232	d	−1.6	+1.7
	16	143 B Capricorni	−20	6.1	02	29	−01	52	264	d	−1.8	+1.1
	29	107 B Leonis	+16	6.3	22	27	+06	38	335		+0.4	−1.9
*July	03	h Virginis	−10	5.4	00	46	+05	45	289		−0.2	−1.7
	12	33 Capricorni	−21	5.3	23	15	−03	01	293	d	−0.9	+0.6
	17	10 Ceti	−00	6.4	02	58	−02	04	250	d	−1.5	+1.5
	17	77 Piscium	+05	6.4	23	54	−05	45	247	d	0.0	+1.7
	21	144[1] Tauri	+21	6.5	02	34	−05	24	196	d	+0.6	+2.4
Aug.	6	234 B Sagittarii	−28	5.9	20	56	−01	42	270		−1.8	+0.8
	12	4 Ceti	−03	6.3	21	56	−05	02	235	d	−0.3	+2.0
	12	5 Ceti	−03	6.3	22	16	−04	43	241	d	−0.4	+1.9
	13	155 B Piscium	+03	6.5	22	29	−05	08	265	d	−0.4	+1.6
	17	65 Arietis	+21	6.0	05	38	−00	19	274	d	.....	.....
Sept.	02	183 B Sagittarii	−29	6.2	19	13	−01	22	228		−2.1	+1.6
	04	86 B Capricorni	−24	6.2	19	56	−02	17	212		−1.6	+2.0
	05	143 B Capricorni	−20	6.1	21	24	−01	34	211		−1.3	+1.7
	07	Ψ Aquarii	−09	4.5	23	52	−00	31	225		−1.4	+1.3
	08	27 Piscium	−04	5.1	23	30	−01	34	222	d	−1.2	+1.8
	09	29 Piscium	−03	5.1	01	56	+00	51	192	d	−0.5	+2.0
	12	ρ Arietis	+18	5.6	21	24	−06	20	263	d	+0.2	+1.4
	13	δ Arietis	+19	4.5	06	24	+02	26	197	d	.....	.....
	13	133 B Tauri	+22	5.9	21	53	−05	52	223	d	+0.4	+1.9
	14	33 Tauri	+23	6.0	01	31	−03	08	271	d	−1.2	+1.2
	14	161 B Tauri	+23	6.5	03	01	−00	40	169	d	.....	.....
*	15	136 Tauri	+28	4.6	00	38	−05	50	294	d	−0.4	+0.8
	16	415 B Tauri	+28	6.1	03	45	−02	49	204	d	0.0	−0.7
	28	210 B Scorpii	−29	5.8	21	45	+04	03	323		.....	.....
Oct.	02	35 Capricorni	−22	6.0	19	52	−01	03	195		−1.1	+2.5
*	09	π Arietis	+17	5.2	00	02	−01	48	196	d	−0.3	+2.9
	10	45 Arietis	+18	6.0	04	30	+00	52	183	d	.....	.....
	24	α Scorpii	−26	1.3	17	06	+02	03	303		−1.6	−1.6
Nov.	02	4 Ceti	−03	6.3	18	06	−03	30	205		−0.6	+2.3
	02	5 Ceti	−03	6.3	18	19	−03	07	209		−0.7	+2.2
	03	155 Piscium	+03	6.5	18	17	−03	58	224		−0.5	+2.1
	06	63 Arietis	+20	5.2	22	48	−01	45	261	d	−1.6	+1.1
	10	49 Aurigae	+28	5.1	03	46	+02	30	303	d	−0.9	−2.1
*	11	28 Cancri	+24	6.1	00	15	−05	04	311	d	−0.7	0.0
	12	ν^1 Cancri	+24	5.7	01	30	−03	51	322	d	−1.3	−1.2
	12	ν^2 Cancri	+24	6.4	02	01	−00	52	347	d	.....	.....
	26	K Capricorni	−19	4.8	21	34	+03	59	296		.....	.....
Dec.	03	ρ Arietis	+18	5.6	18	50	−03	31	204		0.0	+2.5
	03	45 Arietis	+18	6.0	18	50	−03	30	284		−1.4	+1.0
	06	136 Tauri	+28	4.6	19	34	−05	32	299	d	−0.6	+0.6
	31	36 Arietis	+17	6.5	01	44	+05	22	270		−0.2	−1.5
	31	63 Arietis	+21	5.2	17	01	−03	57	268		−0.8	+1.4
	31	65 Arietis	+21	6.0	17	50	−03	08	238		−0.7	+1.9

The most valuable observations are made of the immersions, and especially those at the dark limb, which are designated in Table I by the letter "d" after the position angle. When the limb is bright the star becomes difficult to see in a small telescope and for the emersions, it usually happens that the star is out for a second or so before being discovered. It is essential that the observer has a good watch and that he knows the time to the nearest second. If the amateur lives near Toronto, I think his best procedure would be to go down to Ryrie Birks and take the time from their clock, asking the attendant for its error. He should do this in the afternoon preceding his observation and again next morning, to find out how much his watch gained or lost during the night. A little computation will tell the error in the watch at the time of observation. This may seem to the amateur quite a little labour, but he should bear in mind that a single occultation if well observed is a contribution worth while. Do not take the time from local radio broadcast. These announcements are often several seconds in error. If the amateur is a radio enthusiast and has a set that will receive the radio time signals from Arlington directly, he may rely on these as being strictly accurate. These signals are broadcast on wave length 2650 metres, also on short waves about 37 m. and 87 m., at 12 noon and around 10 p.m. Before using radio signals, however, know where they come from and investigate their accuracy. Accurate time may be obtained also from the telegraph stations throughout the province if the precaution is taken to be on hand at noon and hear the signals coming in. It is obviously of little value to observe accurately the time of an occultation as given by the observer's watch unless the error in the watch is known. The ordinary watch will not carry the same rate for more than a few hours, hence it is necessary to compare the watch as soon before and as soon after the observation as possible.

In regard to the actual observation, the use of an ordinary watch is a little difficult. The observer cannot observe the star and his timepiece at the same time and the time lost in looking at the watch after the occultation has occurred introduces an error. If the observer can arrange for a helper he may manage very well, but even then he must proceed in a scientific manner. The first way the amateur would be inclined to work would be to have his

assistant look at the watch, while he observed the star and after giving warning that the occultation was about to occur, indicate the time by a prearranged signal. This method is not good, because even assuming that the observer is actually conscious of the exact instant of occultation, he must then form the word arranged for the signal, his assistant must hear this, mentally issue the command to his eyes to focus accurately on the second hand and read the time. All these processes depend upon nerve impulses, which take time and which operate to make the time read from the watch too late. A much better way is to have your assistant look at the second hand of the watch (if necessary with an eyepiece) and tap out the seconds and count so that, you, at the telescope, can hear. As the star approaches the limb you will hear the signals and between two signals the star disappears. Leaving aside the refinement of interpolating between the signals you can at least judge the time to the nearest second.

Beginning with 1931, we hope to publish in the HANDBOOK of the Society predictions of occultations as visible from Ottawa, Toronto, Winnipeg and Vancouver.

University of Toronto,
Toronto, Can.

Later.—We have since found that the method of getting the time from Ryrie-Birks and the Canadian National Telegraphs is not sufficiently accurate. If possible, further information will be given in the next issue.

THE ASTRONOMICAL WORK OF JOHN S. PLASKETT*

By A. C. D. Crommelin

The medal this year is conferred not for any single outstanding result, but in recognition of the high merit of a long series of researches, extending over a quarter of a century, and marked throughout by a painstaking striving after the highest accuracy attainable, combined with an alertness in discerning problems of stellar motion and stellar physics to which the powerful observational means available might most suitably be applied.

Dr. Plaskett's name became well known to astronomers soon after he joined the staff of the Dominion Observatory, Ottawa, in 1905. The Director, Dr. W. F. King, placed him in charge of the Department of Astrophysics, his instrument being a 15-inch refractor by Brashear. The Ottawa Observatory had only just been completed, as a result of perservering representations to the Canadian Government on the part of Dr. King and Dr. Otto Klotz, which had continued since 1888. It is a testimony to the high reputation gained by the Ottawa Observatory in the first few years of its existence that the larger outlay involved in the foundation of the Victoria Observatory was granted after a very small delay.

The spectroscopic work was practically limited to stars not fainter than the fifth magnitude, and even for these an exposure of an hour was necessary. The aim was not so much to discover new spectroscopic binaries as to obtain sufficient observations of those whose variable radial velocity had been already detected, and to deduce reliable orbits from the resulting measures; a programme was arranged in conjunction with other observatories doing similar work, so as to avoid needless duplication; a few new cases of variable velocity were detected—for example, a small oscillation was found in the radial motion of Rigel, though it is not certain that it arises from orbital motion.

*Address delivered by the President of the Royal Astronomical Society (London), on the award of the Gold Medal of the Society to Dr. John Stanley Plaskett, for his valuable observations of stellar radial velocities, and the important conclusions derived from them. Printed in *Monthly Notices* for February, 1930.

Careful observations were made of Mira Ceti at the unusually bright maximum of 1906 December. The line $H\beta$ was certainly bright, which had not been the case at some previous maxima; $H\epsilon$ was not seen; the titanium bands were prominent; it was deduced that the bright hydrogen lines gave a velocity of recession 15 km./sec. less than the absorption lines.

We must regard as one of the most valuable features of this work at Ottawa the great experience that it gave to our medallist regarding the various errors to which spectroscopic observations are liable, and the best means of eliminating them. One source of trouble was found to be the bad figure of the correcting lens; this lens was placed 32 inches inside the focus of the refractor, its object being to equalise the focal length for light of different colours; this lens was found to suffer from spherical aberration; a new lens, whose surfaces departed from the spherical form, was designed by Professor Hastings, and made by Dr. J. A. Brashear; it shortened the exposure times by 30 per cent.

Plaskett laid down the following rule for the position of the correcting lens: "It must be so placed that the dispersion produced by it is exactly equal and opposite to that given by the atmosphere." He had noticed that the violet region in a certain spectrum was too weak, and found that it could be remedied in this manner.

Flexure in the spectroscope was another trouble; it was alleviated by the insertion of stiffening rods; but in 1909 a new spectroscope, of much greater rigidity, and embodying some features suggested by our medallist, was acquired. He gratefully acknowledged the readiness shown by Dr. King to carry out his suggestions. He noticed the importance of making the jaws of the slit terminate in knife edges. This was not the case at first, the result being increased difficulty in focussing and trouble through reflection from the slides of the slit. He made investigations on the best width of slit to employ; he found that the average star-image at the slit was about 2″ broad; originally he employed a slit width of 1″ only, but experiments showed that widening it to 2″ notably shortened the exposure-time, without any sensible diminution in the accuracy of the measures; further widening, however, gave a rapid falling off in accuracy. I give a few notes on some of the stars for which orbits were found at Ottawa.

ϵ Ursae Minoris is of the fifth magnitude, which is the faintest that can be conveniently observed at Ottawa; a satisfactory orbit was, however, deduced, using observations made by Professor Campbell in 1897 and 1899 to improve the period, which is 39.482 days.

θ^2Tauri has a period of 140 days, with traces of the second spectrum; this star belongs to the Taurus moving cluster, so its distance and radial velocity are known; the value of the radial velocity found at Ottawa, +43 km./sec., is in fair accord with that deduced by Boss from the cluster motion, which was +40.5.

ϕ Persei has attracted a good deal of attention from the peculiarities of its spectrum; at Ottawa it was noted that the spectrum was in part emissive, and that it appeared to vary in character according to the phase in the orbit; there was also an unexplained hump on the descending branch of the velocity curve.

Spectroscopic determinations of the solar rotation were also made at Ottawa, and formulae deduced for the daily angular motion in different latitudes. Our medallist examined the suggestion that atmospheric scattering of light by haze might affect the results, since each region of the sun would have some light from other regions superposed upon it; his conclusion was that no serious error was likely to arise in this manner.

He also made a useful study of the most suitable glass for prisms; he noted that the dense flint glass used in some of the prisms had a yellow tint, and had strong absorption from λ4000 downwards; a bartya light flint glass was found to be much better; the exposure times were found to be reduced in the ratio of 100 to 65 at H_γ, and of 100 to 12 at $H\zeta$.

Dr. Plaskett had for long entertained the dream of obtaining a telescope of larger aperture; this dream was intensified as a result of his visit to Mount Wilson to attend the meeting of the Solar Union in 1910. During that meeting Professor Campbell invited co-operation in obtaining the radial velocities of stars fainter than the fifth magnitude; he had himself obtained observations for a complete catalogue down to that limit. No one actually volunteered at the meeting, but our medallist, who had been impressed by the fact that the 60-inch reflector at Mount Wilson could obtain in five minutes spectra of fifth magnitude stars that needed an

heavenly bodies through the telescope, a diagonal reflector is inserted between the back of the mirror and the spectrograph, giving a convenient position for the eyepiece at no great height above the floor.

The spectra of faint stars can be obtained by putting a small spectrograph at the principal focus of the large mirror, the Cassegrain mirror being removed. Direct photographs can also be taken here. The dome and mounting of the telescope were entrusted to the firm of Warner & Swasey, at Cleveland, Ohio. The mounting is in the German form, the telescope being on one side of the polar axis with a counterweight at the other side. The moving parts are 45 tons in weight, but can be manipulated by electric motors with great ease, at either a rapid or a slow rate.

The dome, 66 feet in diameter, is of steel. With a view of enabling it to take up the temperature of the air as quickly as possible, a space is left between the inner and outer plates, through which the air can circulate freely. The temperature of the spectrograph is controlled by a Callendar recorder, which also gives a graph of temperature changes. I have some slides that show successive stages in the construction, and help us to realize the feelings of satisfaction with which Dr. Plaskett must have watched the telescope of his dreams gradually assuming visible form. We first see the park-like scenery of Saanich Hill; it will be remembered that vegetation plays a useful part in preventing overheating of the soil. We next see the reinforced concrete pier for the telescope and the foundations for the dome. The steel substructure of the dome is seen, and next the steel framework of the dome, as temporarily assembled at Cleveland. Then we see the dramatic moment when the great mirror has been raised on the silvering car, with our medallist standing beside it, and is about to be inserted in the telescope tube. It is an eloquent testimony to the care and skill with which the plans were drawn up and executed that a successful spectrogram of a star was secured within a week of the arrival of the mirror.

Direct photography of the heavenly bodies is not a main feature of the Observatory's work, but a few photographs were taken with substitution of a Newtonian flat for the Cassegrain mirror, partly as a test of the quality of the images. A slide shows the camera in

position, and the screen that covers the opening in the dome, since the open tube would expose the plate to stray light. So far as I know only three such photographs have been published; I show slides of these. Two are in the Society's collection of slides; the clear definition of the dark rifts in the ring nebula in Lyra, and the small star images both in that and in the Hercules cluster, will be noted. The slide of the Orion nebula is copied from a paper print, so it must not be judged so critically as the others. (The originals of the slides will be found in the *Journal* of the R.A.S. of Canada, chiefly in vols. IX and X, 1915, 1916.)

I quote the following from Dr. Plaskett's report: "The driving is perfect, and no trace of any period or irregularity in the following has been detected. The arrangements provided for operating the telescope, for setting on the star, work to perfection, and I have yet to find any part of the design where any improvement could be suggested. In making exposures on star spectra the average time required in changing from one star to the next, from the end of the exposure on one star to the beginning of the next, is less than three minutes, and if the stars are not far part, is generally two minutes. . . . . When we consider that the moving parts weigh 45 tons, the ease of handling is a remarkable evidence of the perfection of design and workmanship."

The Observatory was completed in the summer of 1918. When the quality of seeing was tested it was found that the favourable verdict pronounced by Mr. W. E. Harper, using a $4\frac{1}{2}$-inch refractor was fully justified under the more exacting test of the 72-inch mirror. By 1919 January two lists of new spectroscopic binaries, 30 in number, had been published. A few of these were subsequently found to have been noted elsewhere.

Dr. Plaskett saw that a useful class of stars to study was that of the eclipsing variables, since a combination of the radial velocities with the photometric data enables determinations to be made of the diameters, masses, densities, and the ratio of surface brightnesses of the components. He published data for three such systems in 1919 August: U Ophiuchi, RS Vulpeculae, and TW Draconis; the second system is remarkable, the fainter star having five times the radius of the brighter one, but only one-third of its mass and one 400th of its density. In U Coronae (elements pub-

lished in 1920 June) both components are of type B3, but one has eight times the surface brightness of the other. Some double stars were also examined with the spectrograph: Boss 283 is a wide pair with common proper motion; the fainter star has a very faint close companion; the two brighter stars were both found to be spectroscopic binaries, so that the system contains five stars.

A similar result was found for Boss 497, both components of the visual pair being spectroscopic binaries. The same was found to be true for Boss 1336, 1337.

In addition to the observational work the computation of orbits also went on; so early as 1919 February an orbit was published for H.R. 8170, one of the newly discovered binaries; its type is F8, its period 3.24 days, and semi-amplitude of velocity range 62 km./sec. Dr. Plaskett notes his indebtedness to Professor C. A. Chant for the loan of the prism used in the early work of the Observatory; conditions arising out of the war made it impossible to secure suitable glass for new prisms.

In H.R. 8800, magnitude 6.6, type B, it was noted (1919 March) that the K line of calcium did not share in the large shift shown by the other lines; more will be said later about this phenomenon which had been noted by Hartmann in δ Orionis as far back as 1904.

The Victoria Observatory was not completed in time to observe Nova Aquilae of 1918 at its brightest, but good spectrograms were obtained in 1919 and 1920; its magnitude was then 7.0 to 7.5; the colour is stated to have been very blue; the abnormal distribution of light in the spectrum, which alters the appearance of the image with refractors, would not be effective in the reflector. Mr. W. E. Harper discusses these spectra in the *Publications* of the Observatory, vol. I, No. 24; he also gives reproductions of spectra of Denning's Nova of 1920, in Cygnus; the sharp H and K lines gave a radial velocity of -17 km./sec., practically identical with the solar motion in that direction. The absorption bands, on the other hand, gave velocities from -645 km. on 1920 August 24, to -1185 km. on September 28. We see here some growth in the belief that the H and K lines arise from diffused calcium in interstellar space, and are unconnected with the particular star in whose spectrum they are seen; but in some cases their appearance may be modified by the lines from the calcium present in the star itself.

At the end of 1921 the attention of the observers at Victoria began to be turned to the stars of type O. At that date our medallist's son, Mr. H. H. Plaskett, published an important paper on the spectra of three stars of this type (*Publications* of the Observatory, vol. I, No. 28), in which he acknowledged the helpful co-operation of his father. The temperature of 10 Lacertae (Oe5) is given as 15,000°; that of 9 Sagittae (Oe5) as 18,500°; and that of B.D. 35°, 3930 N (Oe) as 22,000°. In the last two stars the absorption lines of Mg^+: are absent; in the last one those of He^+: have also gone. I show a slide of the diagram, in which the gradual changes of intensity of various lines are shown as we pass from type B8 to Oe. Mr. Plaskett uses these results to obtain observational values of various atomic constants; these are in excellent agreement with those found from laboratory investigations, thus justifying the assumption of "identical atomic structure, identical electrons, and identical laws of radiation on the earth and in the stars."

These important results induced our medallist to make a systematic examination of all the stars of types Oe to Oe5 that were bright enough for exact spectroscopic investigation. He expresses his indebtedness to Miss Cannon for the preparation of the observing list, which contained 36 stars known to be of these types, and 13 others suspected to be so. One of the latter was a star of the sixth magnitude in the north part of Monoceros, B.D. +6° 1309, whose position for 1900.0 was $6^h\ 32^m.0$, +6° 13′. It was classified as A5 in Harvard, but as Bop in the Henry Draper Catalogue, in which it was noted that $H\beta$ seems to be slightly bright. We must count it a most fortunate circumstance that Miss Cannon inserted this star in the list, for it proves to be one of the most interesting stars in the sky. The first spectrum obtained, on 1921 December 6, showed that the type was Oe5, and that the star was a binary of high orbital velocity; accordingly the star was frequently photographed, and by 1922 April 5 thirty spectra had been secured. The period appeared to be a fortnight, but this indicated such abnormal masses that it was thought it might actually differ little from one day. Accordingly photographs were taken at different hours of the night, which negatived the short period and showed that a fortnight was right. The minimum masses now come out 75.6 and 63.3 times the sun, so that this is by far the most massive system known. The

semi-major-axis is 0.6 astronomical units, and the velocities 206 and 247 km./sec. The eccentricity is small, 0.035; the system is receding at the rate 24 km./sec., of which Dr. Plaskett estimates that 2.8 may be ascribed to the Einstein gravitational shift, while about 16 is due to the solar motion, the star being in the region of the antapex; further, at the distance of 9300 light-years estimated by Dr. Plaskett, the de Sitter shift, of the presence of which the radial motions of the spiral nebulae give evidence, would amount to about 1 km.

The estimate of the distance of the star was made in two ways: first, by Eddington's curve connecting mass and absolute magnitude; secondly, by using assumed values of surface brightness and temperature of O-type stars derived from Plaskett's own researches. The two methods agreed in giving absolute magnitude -6.3 for the combined light of the pair. Taking its visual magnitude as 6.06, the distance is 2860 parsecs or 9300 light-years. The density was estimated as 0.01, the diameters as $19\frac{1}{2}$ and 18 times the sun's, the luminosities 15,000 and 12,000 times the sun's. Our late Fellow, Mr. Scriven Bolton, drew two pictures for the *Illustrated London News* from these data, of which I show a slide; he has added huge coronae, which are of course imaginary, but stars of such immense luminosity and low density would be likely to have external appendages.

The masses given above were minimum masses, based on the assumption that we see the orbit edgewise. In this case each star would eclipse the other at intervals of about a week, which would produce fluctuations of nearly a magnitude in the combined light. For the stars to pass clear of each other at conjunction with the dimensions given above, i must differ from 90° by at least 17°, which increases the masses to 86 and 72. Dr. Plaskett assumes that no eclipses take place, but I do not regard this as certain. Apparently no measures of the light have been made since the duplicity was known, and observations made before that date give a few abnormally faint values. Thus the star was observed twice in the Leipzig zones of the *Astr. Gessels.* Catalogue, the two estimates of magnitude being 6.0 and 7.5; also in the Harvard determinations, 1879 to 1881, the three estimates are 6.0, 5.8, and 7.1. Dr. B. A. Gould included it in his list of suspected variables from the fact of

some discordances in the published magnitudes. It would seem to be worth while to examine it carefully at the times when partial eclipses are possible, in view of the more exact information that these would afford of the masses and diameters of the stars.

It is not to be expected that this star would have sensible proper motion, but it seemed to me to be worth while to collect all the observations that I could find. They are summarised in the following table, the systematic corrections of Boss having been applied where they were available; all observations are reduced to the equinox of 1875.0:

Right Ascension.		N. Decl.	Catalogue.	No. of Orbs	Mean Date
h m	s	° ′ ″			
6.30	42.48	6 14 20.4	Lalande	1	1794
	41.99	17.9	Pulk., Paris, etc.	7	1858.7
	42.04	18.2	Greenw., Leipz., etc.	6	1884.5
	42.02	18.5	Kust., Toul., Campid.	18	1896.7
	42.93	18.2	Greenwich, Lick	4	1923.0

I inferred from these figures that the total motion could not greatly exceed 1″ per century; I subsequently found that Mr. J. A. Pearce gave it as 1″.14 per century; he did not name the authority for this value.

The fact that the H and K lines in this star were stationary, giving the uniform velocity of +16.0 km./sec., which is almost exactly that due to the sun's motion, practically established the conclusion that these lines arise from gas distributed through interstellar space, not from a cloud surrounding the star itself; for it is incredible that any cloud in the vicinity of these enormous masses, moving with such high velocities, could remain absolutely unaffected. This was a result of very high importance. Dr. Plaskett discussed the question very fully in a paper in *M.N.*, vol. 83, 80 (1923). He showed that the calcium producing the stationary lines must be external to the stars in whose spectra they were observed. He suggested that while the calcium clouds might be spread generally through interstellar space, the production of the spectral lines was probably limited to the regions adjacent to the stars of high temperature, where the gas was ionized by their radiation. It will be remembered that Dr. O. Struve read a paper before

this Society last April, in which he suggested that the intensity of these spectral lines might be used as a measure of the distance of stars in the more remote regions of our stellar system; on the assumption of the truth of this principle, he obtained a position for the galactic centre, close to that obtained by Professor Shapley in an entirely different manner. In the discussion that followed the paper the only doubt expressed as to the safety of using the principle was the suggestion that the distribution of the diffused gas might be far from uniform. Dr. Plaskett put this doubt at rest in a remarkable paper which Professor Eddington described at the meeting of the Society last November; his results seem to establish clearly that the average distance of the absorbing calcium cloud is half that of the star in whose spectrum it is observed; this would indicate that the amount of absorption varies directly as the distance, not according to an exponential formula, as had been suggested.* We are thus placed in possession of a very powerful method of measuring the distances of the remote stars of types B and O; the work of our medallist has played a large part in the establishment of this method, though like many results in astronomy it is due to the combination of the observations and discussions of several individuals.

I think it well to say something about another spectroscopic binary of type O8.5*n*; this is H.D. 1337 = Boss 46; 1900 R.A. $0^h\ 12^m.5$, N. Decl. 50° 53′, which is investigated by Mr. J. A. Pearce in *Publ. of Victoria Obs.*, vol. III, No. 13. This has many points in common with the Plaskett star; their distances from the sun, absolute magnitudes, temperatures, eccentricities, orbital velocities, proper motions (each about 1″ per century) are all practically identical; but the masses of the components of Boss 46 are less; they are 36.3 and 33.8 in terms of the sun; in this case the masses are exactly determinable, owing to the fact that partial eclipses take place, as was recognized by Professor Guthnick in 1919; the loss of light is less than 0.2 magnitude. The star had been announced as a spectroscopic binary at Mount Wilson in 1916,

*A note by Dr. Plaskett in *Popular Astronomy* for February 1930 states: "The investigation establishes the fact that the interstellar calcium is not only uniformly distributed through space, but partakes of the general galactic rotation."

which led Guthnick to examine it with the photo-electric cell. The radii of the components are 23.8 and 15.5 in terms of the sun; they revolve almost in contact with each other in 3.52 days, and are of markedly ellipsoidal shape, owing to tidal action. Their densities are 0.0027 and 0.0091 in terms of the sun's, thus supporting Dr. Plaskett's assumption of 0.01 for the Plaskett star as being of the right order.

Our medallist has given special attention to the stars of type O; he notes that they are extremely rare in space, and all are very distant from us; by combining the radial motions with the proper motions, he has deduced the mean parallax of the O-type stars observed as 0″.0011; the corresponding distance is 300 light-years; the average absolute magnitude is −4, implying brightness 4000 times that of the sun; this is several times as great as that of any of any other spectral class, and shows that this is an exceptional and rare type. The masses range from 10 to 80 times that of the sun, the average being about 40. They are the hottest stars known, their temperatures ranging from nearly 20,000° to about 30,000°. Dr. Plaskett estimates that there are twenty times as many A stars as B stars, and about twenty times as many B stars as O stars; we shall soon see that his observations of these stars give important information about the rotation of the galaxy.

A research of much interest is that on the star υ Sagittarii, an orb which has been the occasion of much discussion. Miss Cannon conjectured that its spectrum might be a composite one, arising from three separate bright bodies. Miss Maury described it as having a primary F2 spectrum with a B8 spectrum superposed on it, the latter at times becoming dominant. At these times the hydrogen lines are double, but the secondary is always on the violet side, with a relative separation of 280 km./sec., if viewed as a velocity. It was from a misundertsanding of this last statement that Dr. Ludendorff was led to postulate the binary character of the star, with the unparalleled minimum masses of 260 and 54 times that of the sun. It was fatal to this suggestion that the doubling of the hydrogen lines was noted by Miss Maury to occur near the times of zero radial velocity. Plaskett's work, indeed, shows that the star is a spectroscopic binary, as had been announced by Wilson twelve years earlier; Wilson's results gave a period of

138 days, and radial motion varying from +60 to −35 km./sec. All of the various types of spectral lines mentioned above share in the same periodic oscillation, indicating that they all belong to the same star, and that only one star of the pair, whose existence is demonstrated, is sufficiently luminous to give a visible spectrum; it is therefore clearly proved that a single star can give a spectrum of a composite character; Dr. Plaskett describes it as a super-enhanced spectrum of type A2, with a B-type spectrum superposed on it. The helium lines of the latter spectrum are narrow, strong, and well-defined, possessing the *c* characteristic. The hydrogen lines have "satellite" lines, that are always on the violet side, at constant distances from their primaries; hence they do not belong to a second star revolving round the first, as Ludendorff supposed; it is conjectured that they may be due to hydrogen ejected from the star, as in the novae; if so, the indicated velocities of ejection in the direction of the solar system are 150, 200, and 300 km./sec.

Dr. Plaskett notes that the star must be a massive one, though not approaching Ludendorff's estimate; assuming that the primary has twice the mass of the companion, which is reasonable when no trace of the second spectrum is seen, he finds the minimum mass of the bright star to be twenty-eight times that of the sun.

I pass now to Dr. Plaskett's contributions to the intensely interesting subject of the rotation of the galaxy. The general idea of galactic rotation is not a new one. The astronomical text-books that I read in my youth nearly all supported Mädler's view that the Pleiades are the centre about which the sun and its neighbours are moving. This view did not hold the field for very long; an epoch succeeded in which doubt was felt whether there was any definite centre of the stellar movements. The discovery by Kapetyn, early in the present century, of the two stellar drifts suggested to Professor Turner the idea that these drifts consisted of the stars respectively approaching and receding from the centre, their orbits being postulated as very elongated, like those of the comets of long period, so that the motion was mainly radial; this supposition led him to locate the centre in the feet of Gemini, R.A.6^h16^m, N.Decl. 12°, its distance from the sun being 30 parsecs. The view that now holds the field was put forward by Dr. Oort in 1927. He was, I think, guided to it by the high rotational velo-

cities that are indicated by the spectroscope in many of the spiral nebulae; this suggested that the rotational speed in any region of the galaxy would be much greater than the peculiar speeds of the individual stars in that region. It may help us to picture the method if we consider a number of passengers, walking in various directions on the deck of a steamer, while the steamer itself is moving in a circle round an island a mile or two away, its speed being some ten times that of the walkers. Then all our previous endeavours to find the centre have been based simply on the movements of the walkers on the deck, disregarding the much higher speed of the steamer. It is clear that we can get no idea of the latter by consideration of the movements of the passengers on the deck. We must make observations of other steamers going round the same centre. In the astronomical problem we must consider the movements of bodies that are as distant as possible from the solar system—that is, the stars of types O and B. In these distant objects the proper motions across the line of sight are too small to determine with accuracy, and we have recourse to the radial velocities. It is clear that if the whole system were revolving as a rigid body there would be no relative radial motion; but actually the force to the centre and the velocity are functions of the distance from the centre. Dr. Oort gave a formula for the radial motion in different regions; the most important term of his formula contains as a factor sin $2(l—l_0)$, where l, l_0 are the galactic longitudes of the star and of the centre of rotation; Dr. Plaskett analyzed the radial motions of the stars of types B and O observed at Victoria Observatory (*M.N.*, vol. 88, 395.) The different groups into which he divided them gave accordant results; the position indicated for the centre of rotation was galactic longitude 324°.5 (the origin being the ascending node of the galaxy on the equator of 1900). This agrees with the position found by Oort, and also with that given by Professor Shapley for the centre of the system of globular clusters. This seems to demonstrate beyond a doubt that these clusters are true appendages of the galactic system, not completely independent objects like the spiral nebulae. The distance of this centre from the sun is given by Shapley as 13,000 parsecs. Professor Eddington deduced 330 km./sec. as the sun's velocity in its orbit round the centre (*M.N.*, vol. 88, 330); the

period of revolution would be 200 million years, which happens to be of the same order as the period given by Professor Turner for its revolution round a much smaller orbit with a lower velocity.

The position found for the galactic centre is R.A. $17^h\ 30^m$, Decl. $-31°$ (1900). This is near the junction of Sagittarius, Ophiuchus, and Scorpio, and is in the rift between the two branches of the galaxy. Professor Shapley suggests with great probability that the rift is caused by obscuring clouds, which may conceal the densest part of the galaxy. This suggestion would make it easier to imagine the presence of the necessary mass in the centre of the system. Professor Eddington gives the total mass necessary to control the motion as 270,000 million suns.

It would not be right in giving an account of Dr. Plaskett's work to omit mention of the great help that he received from his staff of assistants; the names of Mr. W. E. Harper, Dr. R. K. Young, Mr. J. A. Pearce, and Mr. H. H. Plaskett perhaps occur the most frequently. The two first mentioned contributed a valuable catalogue of 1100 spectroscopic parallaxes, the calibration curves for the spectral lines employed being drawn from their own researches, so that the catalogue should be quite independent of those published elsewhere.

I have only been able to trace a few of the numerous researches that our medallist has carried out, but I have tried to make them typical of his work in general. The actual conferring of the medal is postponed till the May meeting, at which Dr. Plaskett has promised to deliver the George Darwin Lecture. I am sure that we all join in the hope that he may derive some encouragement from the evidence which the award of the medal affords that his work is highly appreciated by the Society, and in the further hope that he may be able to continue that work for many more years.

REVIEW OF PUBLICATIONS

The Development of Astrophotography and the Great Telescopes of the Future, by G. W. Ritchey. 32 pages, 9½ by 13 in. Published under the Auspices of the Astronomical Society of France, Paris, 1929. Price to members, 50 frs.; to others, 60 frs.

During 1928 and 1929 in this JOURNAL there appeared six articles by Professor Ritchey, dealing with his experience in the construction and use of large telescopes. The present work, which is offered by the St. Gobain Glass Co. and published by the Astronomical Society of France, contains an account of his work, omitting some of the details given in the other articles. It is printed in English and French and has a portrait of the author and one of M. Delloye, the Director General of the Glass Company, who contributes a preface.

Some interesting incidents in Professor Ritchey's work are given, but the outstanding feature is the series of 34 plates of instruments with which Professor Ritchey has been connected and of photographs of celestial objects taken by him. They are printed in a superior manner on the finest paper. One could hardly find better examples of half-tone reproduction.

C. A. CHANT.

NEWS AND COMMENTS

The "Soirée" of the Ottawa Centre of the Royal Astronomical Society of Canada, held at the Dominion Observatory on May 2, was well attended. Members and their friends inspected the work of the various divisions as well as observing with the large equatorial.

The Eastern Section of the Seismological Society of America held its annual meeting at Washington, D.C., May 7-8, on the first day at the Bureau of Standards, and the second day at Georgetown University. The newly elected officers are: Rev. Joseph Lynch, S.J., of Fordham University, Chairman; Dr. Stephen Taber, of the University of North Carolina, Vice-Chairman; N. H. Heck and H. E. McComb, both of the U.S. Coast and Geodetic Survey, Secretary and Treasurer, respectively, and these selected Mr. Ernest A. Hodgson, of the Dominion Observatory, Ottawa, to complete the Executive Committee. A committee was appointed to consider ways of reducing the routine work of reporting earthquake data. An interesting and instructive series of papers was presented at the sessions. (E.A.H.).

Dr. Charles E. St. John, of the staff of the Mount Wilson Observatory, delivered addresses on "Exploring the Sun's Atmosphere", "The Natural Constitution and Extent of the Universe", and "The Observational Status of the Einstein Theory", on May 6, 7 and 8, as the scientific symposium lectures given each spring under the auspices of the Buffalo Society of Natural Sciences, Canisius College and the University of Buffalo.

Messrs. W. G. Hughson, Samuel Gold and M. M. Thomson have recently been appointed to the staff of the Dominion Observatory. Miss Alice W. Turner and Mr. W. M. Kenny have been appointed as summer assistants at the same observatory, and Messrs. Paul ten Bruggencate and H. H. Plaskett at the Dominion Astrophysical Observatory. Recently, Mr. Plaskett, formerly on the staff of the latter observatory, was promoted to a professorship of astrophysics at Harvard University.

REDeL.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Locating Variable Stars

Query.—Can you give me information regarding the way to locate variable stars below naked eye visibility? I have a recollection of a publication called, I believe, "Atlas Stellarum Variabilium," but am not informed as to its nature. Would it be suitable for an amateur like myself, possessing only a small telescope with altazimuth mounting?—Oscar Whittaker, Box 248, Hollyburn, British Columbia.

Answer.—By writing to Professor Leon Campbell, Recording Secretary of the American Association of Variable Star Observers, Harvard Observatory, Cambridge, Mass., you can probably obtain a blue-print of the field of any variable, and any other assistance desired.

An Old Poem on the Comet of 1811

Query.—I am enclosing some verses which I found a short time ago while looking over some old newspapers and clippings. The extract was published in the *Almanack* of the Victoria Chemical Company of Toronto in 1873. How can I get the rest of the poem? —Fred L. Troyer, 123 Keewatin Ave., Toronto 12.

Answer.—The extract sent is printed below. The poem, of course, will be found in a volume of the poems of James Hogg, who died in 1835; but if such is not accessible it may be seen in Chambers's *Cyclopedia of English Literature.*—Editor.

"In October and November, in the year 1811, a brilliant comet appeared, and was visible during the autumn to the naked eye. It was reckoned by many that this was the same comet that appeared at the birth of our Saviour. Hogg, 'The Ettrick Shepherd,' wrote a poem entitled

'TO THE COMET OF 1811'

from which the following verses are extracted:—

"Stranger of Heaven! I bid thee hail!
Shred from the fall of glory riven,
That flashest in celestial gale,
Broad pennon of the King of Heaven.

Art thou the flag of woe and death,
From angel's ensign-staff unfurled?
Art thou the standard of his wrath
Waved o'er a sordid sinful world?

No, from the pure pellucid beam
That erst o'er plains of Bethlehem shone,
No latent evil we can deem,
Bright herald of the eternal throne!

. . . . . .

Where hast thou roamed these thousand years?
Why sought these polár paths again,
From wilderness of glowing spheres
To fling thy vesture o'er the wain?

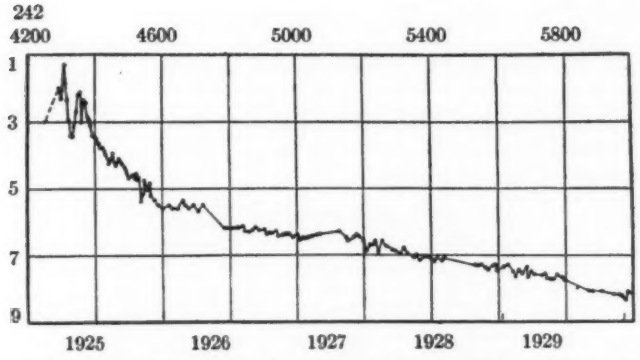
. . . . . .

To brush the embers from the sun,
The icicles from off the pole;
Then far to other systems run,
Where other moons and planets roll!

And long, long may thy silver ray
Our northern arch at eve adorn;
Then, wheeling to the east away,
Light the gray portals of the morn."

Light-Curve of Nova Pictoris

This star was discovered by Watson on May 25, 1925 (see this Journal, Vol. 19, p. 288, 1925), and its light-curve to the end of last year, prepared by Leon Campbell, is given in Harvard College Observatory *Bulletin* No. 874. It is reproduced herewith. As will be seen, the star has been declining steadily in brightness but has not yet reached the ninth magnitude. The irregularities indicated are believed by Professor Campbell to be real as the curve is based on numerous observations made at short intervals.



Light Curve of Nova Pictoris. Ordinates are visual magnitudes, abscissae are Julian Days (above) and years (below).

A Solar Halo Seen at Haileybury, Ont.

Mr. W. H. Tuke, of Haileybury, Ont., sends the sketch reproduced herewith of a halo seen on March 21 from 4 p.m. until sundown. The mock suns on either side of the sun *S* were at times too brilliant to look at with unprotected eyes. The outer circle, though incomplete and not so brilliant as the inner one, was very beautifully coloured, especially at the part where it joined the reversed arc. At times it would compare well with a summer rainbow.

Solar Halo
Seen by W. H. Tuke, at Haileybury,
Ont., from 4 p.m. to sundown, March 21, 1930

Photograph of a Rainbow

Photographs of the rainbow are not easy to obtain and we are pleased to reproduce herewith one taken by Miss Thibaudeau, a member of the Montreal Centre of the R.A.S.C. The Editor would be pleased to receive photographs or sketches of phenomena observed by the members.

Photograph of Rainbow
Taken in the summer of 1929 by Miss Thibaudeau,
Montreal Centre, R.A.S.C.

The New Planets (?)

It will be months, or even years, before the status of the objects discovered at Flagstaff and Ottawa may be definitely settled, but

they are certainly exceptional bodies. Our readers will be interested in the following outline of the search for a trans-Neptunian planet, which appeared in the *Manchester Guardian.*

The existence of a trans-Neptunian planet has been suspected for over half a century. The first astronomer to adduce evidence in support of such a planet was the late M. Camille Flammarion, the gifted and versatile Frenchman who was so well known in his day as a popular expositor of astronomy He noticed that all the periodic comets in the solar system have their aphelia, or points of their orbits farthest from the sun, near to the orbit of a giant planet. Jupiter, Saturn, Uranus, and Neptune, he concluded, each have comet families under their control. "The third comet of 1862 and the swarm of shooting stars of August 1," wrote Flammarion "follow an orbit of which the aphelion is beyond Neptune's orbit. There should exist there a large planet, sailing at 4,000,000,000 miles from the sun in a revolution of 330 years."

Professor George Forbes, of Glasgow, from a more detailed study of these cometary orbits, came to the conclusion that not one but two planets existed, with periods respectively of 1,000 and 5,000 years. Latterly Forbes concentrated on one of these hypothetical bodies, to which he assigned a place in the sky in the constellation Libra. A search for this body was made by an Irish astronomer, Mr. W. E. Wilson, but without success. As is well known, Neptune was discovered mathematically by Leverrier and Adams through the minute irregularities in the motion of Uranus caused by the pull of the then unknown planet. It might be thought that a trans-Neptunian planet would make its existence known through irregularities in Neptune's movements. No inexplicable perturbations of Neptune have manifested themselves, but it ought to be remembered that Neptune has described only one-half of its orbit since its discovery, and so it is too early to draw any definite conclusion from movements of Neptune.

But there are some minute residual perturbations of Uranus which are not due to Neptune, and various attempts have been made to deduce from these perturbations the elements of a hypothetical trans-Neptunian planet. An American astronomer, Professor D. P. Todd, was the first to use these Uranian perturbations, and from these he deduced for the trans-Neptunian planet a period of 375 years. Within the last fifteen years two of the greatest American astronomers, Professor W. H. Pickering and the late Professor Percival Oowell, have essayed the task of tracking down the supposed planet.

In 1909, Pickering assigned to the unknown a position in the constellation Gemini, but an elaborate search by the astronomers at the Harvard College Observatory led to no result. A few years later the late Dr. Lowell tackled the problem in an elaborate "Memoir on a trans-Neptunian planet." He found for the unknown planet a period of a little less than 300 years, a distance of over 3,720,000,000 miles from the sun, a mass seven or eight times that of the earth, and an apparent brightness of the twelfth or thirteenth stellar magnitude. He was unable, however, to assign to the hypothetical planet a definite place in the sky. Dr. Lowell's investigation suggested two possible directions (one in Gemini) in which the unknown might be located, but he concluded that "precise prediction of its place does not seem to be possible."

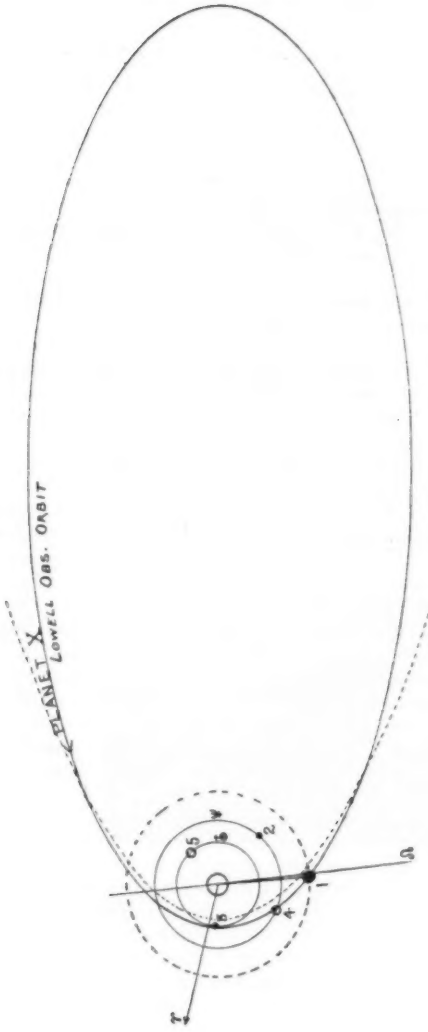
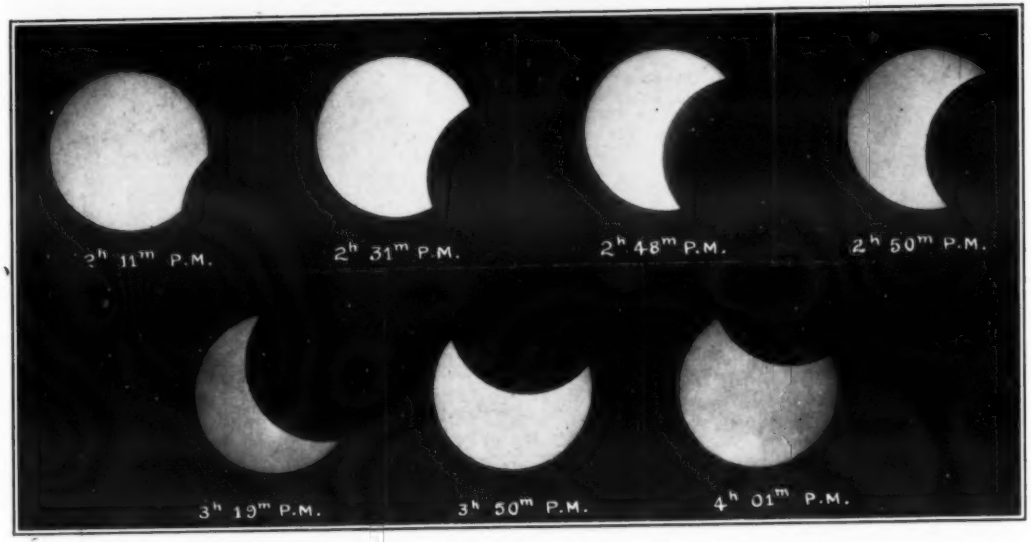


DIAGRAM OF THE PUBLISHED ORBITS FOR PLANET X. The full curve represents an orbit by the Lowell observers based on two months' observations. The planet is at 1 at the present time, and the slight elongation in the dot indicates the motion in two months. Uranus is at 3, and Neptune at 2. According to this orbit, the planet passed perihelion about 1897, when Uranus was at 5 and Neptune at 4. The lighter broken curve represents the parabolic orbit from the Berkeley observatory, California, and the dotted circle represents an orbit published by the Cracow observatory. All three orbits agree in placing the planet at the present time at about 40 astronomical units. They also agree in the position of the node and the inclination of the orbit plane. The other elements are very uncertain, due to the limited time covered by the observations, and no importance should be attached to the wide divergence of the ellipse, parabola and circle.



PHOTOGRAPHS OF SOLAR ECLIPSE OF APRIL 28, 1930

made at Hamilton by J. A. Marsh with a 4 x 5 inch sun camera attached to a 5-inch refractor. Note the moon's limb cutting the sun size at 2.50 p.m.

Two or three years ago, however, Pickering again attacked the problem, and he, more daring than Lowell, assigned to the planet a position in the constellation Cancer, not very far from the point in Gemini assigned in his investigation of 1914.

Orbit of Planet X; the Ottawa Object

Three preliminary orbits of Planet X have been announced and are summarised in the table below. The first is by Bower and Whipple, under the general direction of Leuschner at Berkeley, Cal. The orbit is indeterminate, a near circle or a parabola, shown by the broken lines in the diagram, apparently satisfying the observed positions. The second is by Banachiewicz of Cracow, Poland. It assumes the orbit to be a circle. The third is by the Lowell Observatory staff with the collaboration of Miller of the Sproul Observatory. On account of the short arc of the orbit available, and the extremely small latitudes of the object, the elements are uncertain, especially the eccentricity. It would appear that the node and inclination are fairly well determined, and the latter is much greater than that of any other major planet.

Early Orbits of Planet X

	Berkeley	Cracow	Flagstaff
Longitude of node	109°	109° 42′	109° 21′
Inclination	17°	13° 03′	17° 21′
Semi-major axis	....	.....	217
Eccentricity	....	0 assumed	0.909
Period	....	250 yrs.	3200 yrs.
Distance at discovery	41	37	41.3
Observations used	Mar.16-Apr. 4	Mar. 16-26	Jan. 23-Mar.23

On April 22 Director Stewart of the Ottawa Observatory announced the discovery of an object on plates taken in 1924. It was found while searching for the Lowell object. The orbit is still uncertain. It was shown that the two positions first found can be satisfied by two circular orbits at trans-Neptunian distances and one at an asteroid distance. Further positions on other plates are being sought.

Dr. Dustheimer on the Air

Dr. O. L. Dustheimer, of Baldwin-Wallace College, Berea, Ohio, during the last session has given two series of lectures over WTAM Cleveland. The subjects were:—

Nov. 7—Astronomy, the Oldest of the Sciences.
Nov. 21—The Sun, Our Nearest Star.
Dec. 5—The Moon, the Earth's Satellite.
Dec. 19—The Planets, the Children of the Sun.
April 1—The Ninth Planet.
April 10—The 13-Month Calendar.
April 15—The Evening Star.
April 24—The Solar Eclipse.

In addition to the above, WTAM conducts a Star Gazers' Club. Special maps for each month are sent to members. There are more than 2,000 members in the Club, representing 35 states and several Canadian provinces.

The Solar Eclipse of April 28, 1930

This eclipse was total over about a thousand miles of its central path and annular over the rest of that path. The maximum duration of totality was 1.5 sec. and the maximum width of the shadow path was about 3,000 feet. The chief observation stations were near Camptonville, Yuba Co., California. The Lick expedition, under Dr. J. H. Moore, obtained spectrograms in ultra-violet and infra-red light, but the duration of the eclipse was too short to either see or photograph the corona to its full extent. A number of airplanes allowed photographs of the moon's shadow sweeping over the country to be taken.

In the Canadian northwest the annular and partial phases were not well observed on account of cloudy and overcast sky. Mrs. P. J. Wells, of Winnipeg, reports that the members of the Winnipeg Centre, by invitation, gathered on the roof of the Hudson's Bay Company's store, but clouds and mist prevented observations. In the neighbourhood of Toronto the weather was fine and the partial phase (being 64% at 3.20 E.S.T.) was well observed. A note from Mrs. N. R. Sissons, of Brampton, states that the eclipse was well observed there. She reports seeing bright streaks just at the cusps of the crescent sun. At Hamilton, Mr. J. A. Marsh made a number of photographs, which are reproduced in Plate VII.

At the University of Toronto, the times of the beginning and the ending of the partial phase were observed, as follows:—

Beginning	2h	00m	39s	E.S.T.
Ending	4	31	37	

Freakish Action of Lightning

Some examples of the peculiar behaviour of lightning are described in a Toronto newspaper of May 3. Electrical storms occurred in the southwest part of Ontario on May 1st and 2nd. A farmer near Galt on the afternoon of the 2nd was walking beside his team of horses on the way to a barn for shelter when a flash of lightning killed the animals and one fell on him. He was rendered unconscious. He suffered burns about the chest and legs and the heel of one shoe was burned off. His injuries are serious.

A despatch from St. Thomas, dated May 2, describes still more remarkable effects. It is printed herewith:—

> Lightning played strange pranks in this district last night, with serious results. While milking a cow in his uncle's stable, two miles north of the city, Harold Wilson, aged 16 years, was thrown through the stanchions against the stable wall, fracturing his left hip, by the force of a bolt of lightning. The bolt is believed to have struck the stable floor under the cow, which escaped injury. The pail of milk was thrown into the stall, landing right side up with scarcely a drop spilled. The boy was brought to the hospital this morning, where an X-ray examination revealed the fracture. He was shocked by the lightning and will be confined to the hospital for some time.

C. A. C.

MEETINGS OF THE SOCIETY

At Toronto

March 4.—The regular meeting was held in the Physics Building of the University at 8 p.m. Mr. J. R. Collins was in the chair.

The following were elected to membership:

Mr. J. W. D. Chesney, 340 West Huron Street, Chicago, Ill.

Mr. Wilson Talley, Berlin, New York.

The Constellation "Taurus" was mapped on the board, and described in detail.

Mr. J. R. Collins then introduced the subject of the evening, "The formation of images in the telescope." It was stated that the origin of light is generally regarded as being due to an interatomic disturbance of some kind which spreads outward in an ever widening shell as it proceeds from its source. The density and elasticity of the media through which it passes determine its velocity. One or both of these properties are modified within the boundaries of a glass lens, and the velocity is lessened within such surfaces and regained again upon emergence therefrom. It is this that makes possible the formation of an optical image by a glass lens. What is known as the irrationality of dispersion through special kinds of glass has made possible the modern refracting telescope.

A focus of ten inches gives an image of standard size, (say) a magnification 1; every ten inches added to the focus adds a magnification 1 to the image, and every fraction added thereto adds to the size of the image. Approximately the focus of a refracting system is three times the length of the centre of curvature of the combined surfaces. The reverse of this is true with the reflecting telescope. Here the focus is but one-half the length of the reflecting curved surface, and the images of distant objects from the outer portion of the reflector are larger than those formed by the central portion. This becomes marked when the aperture is greater in proportion than 1 to 12 of the focal length.

Mr. M. S. Groh then took up the subject and by a simple demonstration showed that plain glass allowed parallel rays to pass through with only slight interruption to intensity, a bevelled piece of glass refracted the rays to one side, a mirror reflecting them back according to the angle of the mirror to the rays of light. As we are only interested in distant objects we confine our magnifying of this object to the light received over an area extending over not more than approximately half a degree at the most, this being a portion of light that is received at the centre of the image and enters the eye-piece, which further refracts the rays, so that an object that may be seen with the naked eye of not more than half a degree in extent may be viewed through the eye-piece over an area of a great many degrees according to the magnifying power of the eye-piece.

The reflecting telescope is considerably simpler in design and much more attractive to the amateur. It gathers its light by reflecting the rays to a focus where it is then refracted at large angles as it passes through the eyepiece, in the same way as in a refracting telescope. The amount of light received in a 6-inch lens is somewhere in the order of 3,000 times that received by the unaided eye, and therefore allows ample light to compensate for various losses, including magnification.

Mr. S. C. Brown explained the silvering of a mirror, and Mr. H. L. Rogers added a few remarks.

March 18.—The regular meeting was held in the Physics Building of the University, Mr. J. R. Collins in the chair.

Mr. N. B. Massey, St. Andrew's College, Saskatoon, Sask., and Mr. Reuben. J. Wood, 3573 Raymar Boulevard, Cincinnati, Ohio, were elected to membership.

The Chairman spoke briefly on the constellation Gemini, showing drawings to illustrate its position. He also referred to the recently discovered trans-Neptunian planet and showed its position. The Memoir by Prof. Lowell, printed in 1915, on the search for this supposed planet, was shown.

The Chairman then introduced the lecturer of the evening, Dr. A. V. Douglas, of McGill University, who spoke on "Jeans and Eddington." James Hopwood Jeans and Arthur Stanley Eddington are two of the most outstanding men of science of our day and generation. Both of them were born in England, Jeans in London in 1877 and Eddington in Kendal in 1882. Both became Wranglers in the Cambridge Tripos, and were elected to Fellowships in Trinity College after becoming winners of the Smith's Prize. Both men have distinguished themselves in mathematical researches in Physics and Astrophysics, while Jeans as a cosmologist and Eddington as a Relativist and Philospoher, have won world-wide recognition, and profoundly influenced modern thought. Both are Fellows of the Royal Society, and are Past-Presidents of the Royal Astronomical Society.

Jeans lectured on applied mathematics at Cambridge and at Princeton and published his *Dynamical Theory of Gases* and his *Electricity and Magnetism* before 1912. The theoretical researches of Poincaré, Roche and Sir George Darwin captured his interest, with the result that he carried the investigation of the equilibrium forms of rotating bodies a stage further than the earlier workers had done and applied the "pear-shaped fission theory" to the formation of binary stars; the "equatorial emission theory" to the formation of a star galaxy or spiral nebula; and he carefully investigated the "tidal disruption theory" of the formation of the solar system. Jeans attacked the problem of the age of the stars from three different approaches and concluded that all the evidence pointed to an age of ten million million years. He has studied and speculated upon the internal physical state of the stars, the source of their radiant energy and the course of evolution both for an individual star and for the universe as a whole.

Eddington was Chief Assistant at Greenwich for several years prior to 1913 when he was appointed Plumian Professor of Astronomy at Cambridge University. His first well-known work was on star-streaming. Next came his realization of the important part played by radiation pressure in the equlibrium of a star. This

gave for the first time a logical explanation of the observed facts about the small range in values of the masses of the stars as contrasted with the very great range in their luminosities. Since 1916 Eddington has produced one important paper after another dealing with the internal constitution of the stars. In 1924 he found a relation between the mass and luminosity of a star which has had far-reaching consequences, and over this and other points has waged almost uninterrupted warfare with his critics Jeans, and more recently Milne. As Professor Eddington has humorously remarked, "Onlookers will feel sure that some corpse is stretched upon the ground but the disputants disagree as to whose corpse it is!"

Remarkable confirmations were made within the last ten years at Mount Wilson Observatory of predictions that had been made by Eddington from purely theoretical considerations regarding the immense size of stars like Betelgeuse, about 300 times the diameter of the sun; and the very great density of a star like the dwarf companion of Sirius—more than one ton per cubic inch. As an exponent of the relativity theories, Eddington ranks first among British writers. But he has also been a contributor to these theories, his "world-building" with mathematical symbols starting from the least possible number of assumptions, and arriving at a map or graph of the universe containing the relations of mass, momentum, stress, gravitation and electro-magnetic phenomena places him with Einstein, Weyl and De Sitter as amongst the foremost constructive mathematical thinkers of the age.

As a philosopher, Eddington is Platonic in his insistence upon the intrinsic part played by mind in the picture of the universe which man constructs for himself. He stresses the purely symbolical character of the world built up by the measurements of the physicist. The underlying reality is untouched by these methods of approach. Einstein, Weyl, and De Sitter attempt to produce models of the universe. Eddington labels the result of his world-building as merely a map or graph of the actual world. We can put "symbolic" knowledge, the result of physical measurements, into this map, but "intimate" knowledge, the essential contribution of the mind, cannot be introduced. With regard to atomicity and the indeterminacy principle, he believes that here we are touching the most fundamental aspects of the physical world, in contrast to the conservation of energy, gravitation and so on, laws which are not primary but which are of the nature of identities inevitably true because of the way in which man, as man, sees and interprets the world about him. Being a Quaker, with sincere mystical insight, Eddington lays great stress on the reality of the unseen world. His philosophical approach as a scientific man gazing at the question is through "intimate" knowledge with its dependence upon mind, and through man's consciousness of the passage of time—the sense of being and consideration of the significance of the word "ought," a word having no meaning as applied to the merely physical world where what an atom or a star *does* and what it *ought to do* are always one and the same thing. The essence of Eddington's attitude of mind may be found in these passages from his own writings:—"Scientific investigation does not lead to knowledge of the intrinsic nature of things. . . . . We are dealing in physics with a symbolic world. . . . . The measure numbers, which are all

that we glean from a survey of the world, cannot be the whole world . . . . we all know that there are regions of the human spirit untrammelled by the world of physics. . . . . Life would be stunted and narrow if we could feel no significance in the world around us beyond that which can be weighed and measured with the tools of the physicist or described by the metrical symbols of the mathmatician. . . . . You will understand the true spirit neither of science nor of religion unless *seeking* is placed in the forefront. . . . . Our belief is not that all the knowledge of the universe that we hold so enthusiastically will survive in the letter; but a sureness that we are on the road."

The thanks of the meeting to the lecturer was proposed by Dr. R. K. Young, seconded by Mr. A. F. Hunter, and supported by Dr. H. R. Kingston, who expressed intense enjoyment and appreciation of the very able and well-prepared lecture.

AT HAMILTON

Minutes of the Re-organization Meeting of the Hamilton Centre of the R.A.S.C.

Having received the assurance that the Council of the Society would approve of the re-organization of the Hamilton Centre, provided a sufficient number of members could be secured, a meeting was held for this purpose on April 8, 1930, in the Public Lecture Hall. About two hundred people were present.

J. A. Marsh opened the meeting by explaining briefly the steps that had been taken by a group of men and women interested in reviving the centre, and who had acted as an organization committee in arranging the details of the first meeting.

The speaker then asked the meeting to appoint a chairman, and it was moved by T. H. Wingham, and seconded by D. J. Parry, that Rev. Dr. Marsh take the chair and conduct the organization meeting.

Dr. Marsh spoke of the activities of the first Centre formed in Hamilton in 1901, and outlined briefly the aims of the Royal Astronomical Society of Canada, and conditions of membership, etc., and, calling for a motion to organize, proceeded with the election of officers.

It was moved by Dr. Gordon M. Jackson, seconded by W. T. Goddard, that a centre of the Royal Astronomical Society of Canada be formed in Hamilton; that the names of sixty-eight people desiring membership, as read by the chairman, be put on the roll as active members and that the nominees as recommended by the organization committee be elected as officers for 1930 as follows:

President—Mr. J. A. Marsh

Vice-Presidents—Dr. W. R. Jaffrey, Rev. John Samuel, Mr. W. J. Hocking.

Secretary-Treasurer—Miss Beatrice Marsh.

Recorder—Miss J. I. Jackson.

Librarian and Curator—Mr. T. H. Wingham.

Council—Mr. J. J. Evel, Capt. C. P. Hardy, Mr. W. F. Mallory, Dr. Gordon M. Jackson, Miss Winnifred Parker, Miss E. J. Reynolds, Mr. W. T. Goddard, Mr. Chas. E. Bull, Mr. C. F. Marshall, Mr. R. Wynne, Mr. E. H. Darling

Motion carried.

It was moved by T. H. Wingham, seconded by R. Gage, and carried, that Rev. Dr. Marsh, first President of the Royal Astronomical Society of Canada in Hamilton in 1901, be made Honorary President.

The President then took the chair and called for a motion that the time and place of the next meeting and the programme be left in the hands of the Council. Motion was moved, seconded and carried.

The lecturer of the evening, Rev. Dr. Marsh, then gave a most interesting illustrated talk on "Our Sun", after which several questions were asked and answered to the satisfaction of the audience.

At the conclusion of the lecture, Alderman Curry Gardner, representing His Worship, the Mayor and the Hamilton City Council, spoke a few words of welcome to the new Society, and tendered the promise of co-operation from that body.

The meeting adjourned to meet at the call of the Council.

Members—Robert Gage, J. J. Evel, E. H. Darling, R. Wynne, W. T. Goddard, J. A. Marsh, J. Somerville, W. H. Milne, D. J. Parry, Chas. Cunningham, A. H. Tallman, W. D. Simpson, J. Benner, Dr. D. B. Marsh, J. A. Little, C. F. Marshall, Geo. Emery, Joseph Clarke, Olaf Nielson, Douglas Johnston, Capt. C. P. Hardy, Chas. W. Heming, Dr. W. D. Ferguson, Dr. Gordon C. Jackson, W. Acres, Harvey Murphy, A. J. Bawdon, Chas. E. Bull, Robert E. Beal, Geo. E. Campbell, Dr. W. R. Jaffrey, Rev. John Samuel, Hugh W. Rodger, H. Sneyd, W. F. Mallory, Rev. F. W. Ellis, T. H. Wingham, Bishop Owen, Dean Broughall, W. J. Hocking, Miss E. J. Reynolds, Miss M. E. Campbell, Miss M. Burkholder, Miss I. S. Walker, Miss M. Fairfield, Miss Iola McLeod, Miss W. Parker, Miss E. Pyfrom, Miss Beatrice Marsh, Mrs. Ruby L. Oaten, Miss Edith Dunlop, Miss J. I. Jackson, Miss Clara Hewitt, Mr. Raymond Meyers, Mrs. Raymond Meyers, H. J. Jackson, Miss Ester Anderson, Mr. A. J. Anderson, L. V. Johnson, Walter Scott, Mrs. W. T. Goddard, D. W. MacLean, W. J. Seal, Miss Lavina Laventure, G. E. Campbell, A. G. Hewish, D. P. Rous, Miss E. S. Kennedy.

BEATRICE MARSH,
Secretary.

The Royal Astronomical Society of Canada

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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

The objects of the Society, incorporated in 1890, are:

(*a*) "To study Astronomy, Astrophysics and such cognate subjects as shall be approved of by the Society and as shall, in its opinion, tend to the better consideration and elucidation of Astronomical and Astrophysical problems; and to diffuse theoretical and practical knowledge with respect to such subjects.

(*b*) To publish from time to time the results of the work of the Society; and,

(*c*) To acquire and maintain a Library, and such apparatus and real and personal property as may be necessary and convenient for the carrying into effect of the objects of the Society."

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal, P.Q.; Ottawa, Ont.; Toronto, Ont.; London, Ont.; Winnipeg, Man.; and Victoria, B.C. Among its 800 members are a number of the leading astronomers and scientists of the world, many amateurs, and in addition, many laymen who are interested in the culture of the science.

Membership in the Society is open to anyone interested in Astronomy. The annual dues are $2.00; life membership $25.00 (no further dues).

The annual fee includes subscription to the publications.

The Society publishes a monthly JOURNAL containing about 500 pages of interesting articles, and the yearly HANDBOOK of 72 pages containing valuable information for the amateur observer. Single copies of the JOURNAL or HANDBOOK are 25 cents.

The Library and the Offices of the Society are at 198 College St., Toronto, Ont. Applications for membership, or for further information should be addressed to:

General Secretary—Dr. Lachlan Gilchrist, 198 College St., Toronto, Ont., or the Secretary of any Centre as given on the previous page.